NASA TECHNICAL MEMORANDUM

NASA TM-76646

SYSTEM FOR ACQUISITION AND ANALYSIS OF DYNAMIC TESTS ON AIR INTAKES

Perrier P., Delahaye B., Laruelle G.

Translation of "Systeme D'Acquistion et D'Analyse pour Essais Dynamiques D'Entees D'air", NATO, AGARD, Symposium on Aerodynamics of Power Plant Installation, held in Toulouse, France, May 11-14, 1981. ONERA TP-1981-37, 1981, 15 p.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D. C. 20546 DECEMBER 1981

STANDARD TITLE PAGE

1. Report No. NASA TM-76646	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SYSTEM FOR ACQUISITION AND ANALYSIS OF DYNAMIC TESTS ON AIR INTAKES		5. Report Date DECEMBER 1981
		6. Performing Organization Code
7. Author(s) Perrier P., Delahaye B., Laruelle G.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw- 3542
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Systeme D'Acquistion et D'Analyse pour Essais Dynamiques D'Entees D'air", NATO, AGARD, Symposium on Aerodynamics of Power Plant Installation, held in Toulouse, France, May 11-14, 1981. ONERA TP-1981-37, 1981, 15 p. (A81-39240)

16. Abstract

This article is a study of the problems of compatibility between the airflow developed through the aircraft's air intake ducting and its suitability to the jet engine.

The work was done by a three-cornered collaboration between aircraft manufacturer, engine manufacturer and research organization.

A review of the various functions of the air intake is presented. A proposed solution to measure the various parameters is described. The specifications and details of the system permit measurements with a satisfactory reliability on the test bench, as well as in the wind tunnel or in flight.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 53	22. Price

/001/ ***

O N E R A

NATIONAL OFFICE FOR AEROSPATIAL RESEARCH AND DEVELOPMENT

SYSTEM FOR ACQUISITION AND ANALYSIS OF DYNAMIC TESTS ON AIR INTAKES

by PERRIER P.*, DELAHAYE B.**, and LARUELLE G.

Paper presented at the AGARD/FDP Symposium on "The Aerodynamics of Power Plant Installation

Toulouse, 11-14 May 1981

*AMD-BA 92214 St. Cloud
**SNECMA 77550 Moissy Cramayel

PRINTED SEPARATELY: T.P. Nr. 1981-37.

*** Numbers in margins indicate pagination in original foreign document

SYSTEM FOR ACQUISITION AND ANALYSIS OF DYNAMIC TESTS ON AIR INTAKES

Pierre PERRIER
Avions Marcel Dassault-Breguet Aviation (AMD-BA)
78 Quai Carnot - 92214 ST CLOUD - France

Bertrand DELAHAYE
National Company for Development and
Construction of Aircraft Engines (SNECMA)
77550 MOISSY CRAMAYEL - France

Gerard LARUELLE
National Office for Aerospatial Research and Development
92320 CHATILLON - France

0. INTRODUCTION

Expansion of the flight domain of combat aircraft leads to operational parameters corresponding to a very much greater variation in unsteady aerodynamic characteristics at the air intake of the jet engine than in the past. To determine if this expansion of the flight domain will be effectively acceptable in respect to the compressors and jet engines of the future it is first necessary to acquire a sufficient knowledge of airflows. This knowledge is gained through measurement of a sufficient number of unsteady airflow characteristics. But on the other hand the points of measurement must be limited to an acceptable level, as much from considerations of price as for the possibilities of instantaneous or deferred data reduction. It is this series of measurements, taking that compromise into account, which we will describe in this paper, after having set forth the technical parameters and data processing capacities employed.

This work is the result of a three-cornered collaboration between aircraft manufacturer, engine manufacturer and research organization, the goal of which is to render complementary the researches of each of them, thus permitting an economy of means and an homogenity of methods chosen for the analysis and interpretation of results. It was, for this reason, financed by the Ministry of Defense.

1. EVOLUTION OF THE PROBLEMS OF DEFINING AIRFLOW AT THE INTAKE THE JET ENGINES

1.1 The problems of compatibility between the airflow developed through the aircraft's air intake ducting and its suitability to the jet engine have been ignored for a long time, in consequence of three favorable effects existing simultaneously or partially in earlier military aircraft:

- utilization of compressors whose aerodynamic characteristics were far from the possible maximum before detachment of the blades;

- utilization of extremely long air ducting, of large cross-sectional dimensions, leading to a very good homogenity of airflow at moderate speeds;

- limited flight conditions and moderate angles of incidence and yaw/skid, most often to avoid poorly controlled stalls or the serious risk of entering spins, recoverable only with difficulty.

Avions Marcel Dassault-Breguet Aviation has always aimed at obtaining normal operation of military aircraft at high angles of incidence, to the end of not imposing flight limitations upon pilots, including in the spin condition, the aircraft having been designed for spin recovery (Ref. 1); also SNECMA, on its part, has maintained an equivalent design and quality control of the engines equipping these aircraft. However, the recent and substantial increase in the performance of these aircraft, enabled by the improvement of engines, flight controls and aerodynamics at high angles of incidence, has now led to normal flight capabilities at incidences exceeding 30 degrees and aerodynamic speeds capable of being zero (MIRAGE 2000). Utilization of very long ducting is not always possible or can be very costly in terms of weight; finally, the engines themselves cannot produce an increased thrust/weight ratio without further research on performance, in particular on the compressors. These, being more highly loaded, are consequently nearer to their limits, not only locally but also throughout the entire assembly, and can attain operational extremes with rotors partially or totally damaged.

1.2 We will quickly review the elements involved before characterizing aerodynamic airflow.

1.2.1 It is appropriate, first, to characterize the airflow from the viewpoint of its interaction with the compressor. Spacially, this depends on a knowledge of the airflow upstream of the engine at a given point in time as a function of its radial and circumferential coordinates: this is the graph of the air intake duct. But it is also necessary to understand the interaction between stages, characterized successively as a function of the graph time and the resultant spacing relative to the inter-stage distance as theoretically the inter-stage reaction cannot be ignored. In fact, the tests show that high frequency fluctuations, relative to inter-rotor transit time are not characterized by general separations even when spacial fluctuations, too small in respect to a fraction of the circumference, are buffered by the action of the rotor screen for the stage (Ref. 2).

/003/

1.2.2 The increase of Mach numbers at the compressor entry has led to a diminution in the ratio of diffusion in the air intake between the collar of the duct and the compressor entry. But it has not always been possible to retain very long ducts in the aircraft architecture because of the elevated price paid in the totality of mass of the aircraft. In any event the interaction of rotor aspiration, and their local fields, on the airflow always, in practice, remains weak, contrary to the case of the extra-short ducting in the nacelles used in civil aviation. It is also possible, in the absence of the jet engine, to obtain valuable characterization of airflow in the duct, and this simplifies the tests. The ducts are the site of unsteady phenomena which can be characterized at two different levels:

- either by the fluctuations of a sharply defined frontier between the zones of high pressure and the zones of low pressure, the frequency of which can be associated with the propogation times of disturbances based on the length of the tube;

- or by turbulent fluctuations of speed, in force and direction, of which the lowest frequencies depend directly on the size of the gross turbulence structures, themselves directly limited by the average local diameter of the air duct. These two types of fluctuations are essentially created and sustained at the exterior or at the lips of the air inlet, but it is not excluded that the restraints or excessive curvatures of the duct generate them; the corresponding separations are therefore all the more unacceptable when they occur in the vicinity of the jet engine, as they cannot be absorbed by a sufficient length of ducting.

1.2.3 The causes of disturbances created at the air intake and in its vicinity depend essentially on the flight parameters of the aircraft and its performace expressed in the Mach number, incidence and yaw/skid involved:

a) At low Mach numbers airflow becomes identical to airflow at a fixed point and can be characterized as such, with the exception of the aspiration of boundary layers induced by aspiration along the neighboring walls (such aspiration can lead to highly erratic vortical air flows).

b) At high super-sonic Mach numbers major problems of distortion at the engine intake are created by irregularities of the aerodynamic field and the inequalities of upstream shock waves. The engine intake graph can be characterized by zones of three types:

- zones where the output is close to the average level desired and which depend only upon distortions of the upstream field created by isotropic recompression devices or by retained oblique shock waves;

- zones where the output is close to the output of direct shock waves, worsened when associated with hyper-speed zones in respect of upsteam airflow;

- zones where the output depends not only on the shock wave output, but also on losses of turbulent loads created either by the interaction of shock waves (wall boundary layers) or by local separations.

Thus distortions are maximal for upstream airflows at high Mach numbers and during non-uniform operation. Non-uniformity results from direct or oblique shock waves having, it is understood, no general reason for remaining stationary. Except for strongly turbulent zones created by separations close to the walls of the duct, the airflow is very well characterized by losses of stagnation which are a reflection of the upstream entropic losses following the very weak diffusion of the latter in the absence of characteristic turbulence limits. As these variations in output can be extremely high at Mach 2, and provoked the first important problems of unacceptable distortions at the compressors, and as they are simply measured by sampling the unsteady stagnation pressures, the corresponding graphs are well understood and are currently being exploited. They cannot, however, take into account the rotation of the assembly or local turbulences generated by restraints or angles.

c) For intermediate Mach numbers, where the load losses due to increased entropy in the shock waves are weak, the preponderant phenomenon is, contrary to the preceeding cases, the fluctuation of the speed vector; this is created by the gross vortices of the turbulent structures which are generated in general at the lips of the air intakes, or in their vicinity after a separation. The maximal fluctuation of loss of stagnation pressure read by a pitot measures, therefore, the variation between the stagnation pressure and the external airflow. That is to say, the aircraft stagnation pressure and a pressure a little lower than the static pressure at the engine intake in the case of return airflow at the compressor intake, depends largely on the Mach number of the aircraft. There is a combiation of incidence and maximum yaw/skid, of maximum engine power and the Mach number of the aircraft towards the highest altitudes and in trans-sonic flight, which will give rise to the largest separations associated with maximal fluctuations of speed and pressure and, often, to the onset of significant entropic losses. This is the zone of the flight domain which is likely to be the most critical and which is further characterized by a fluctuation in the direction of flight speed rather than by its intensity. It is not very well measured by pitot reading, necessitating more appropriately a measurement of local incidence. In particular, all of the vortices whose axes are collinear to the axis of the duct are measurable only in terms of local incidence.

In regard to turbulent airflows it is important, however, to distinguish two scales of dimensions or of frequencies of very different interest: the frequencies corresponding to the grossest turbulent structures on the order of size of the air duct (and unfortunately with the present inlet speeds of compressors of a frequency close to the engine rotational speed) and the very much higher frequencies of the internal turbulence, of which the intensity affects quite directly the extinction of the gross structures. The first are the only ones of interest in regard to the functioning of the jet engine; the second can be measured, above all, to aid in the understanding of the internal dissipations of the air duct. They also give the general level of turbulence at the jet engine intake (Fig. 2).

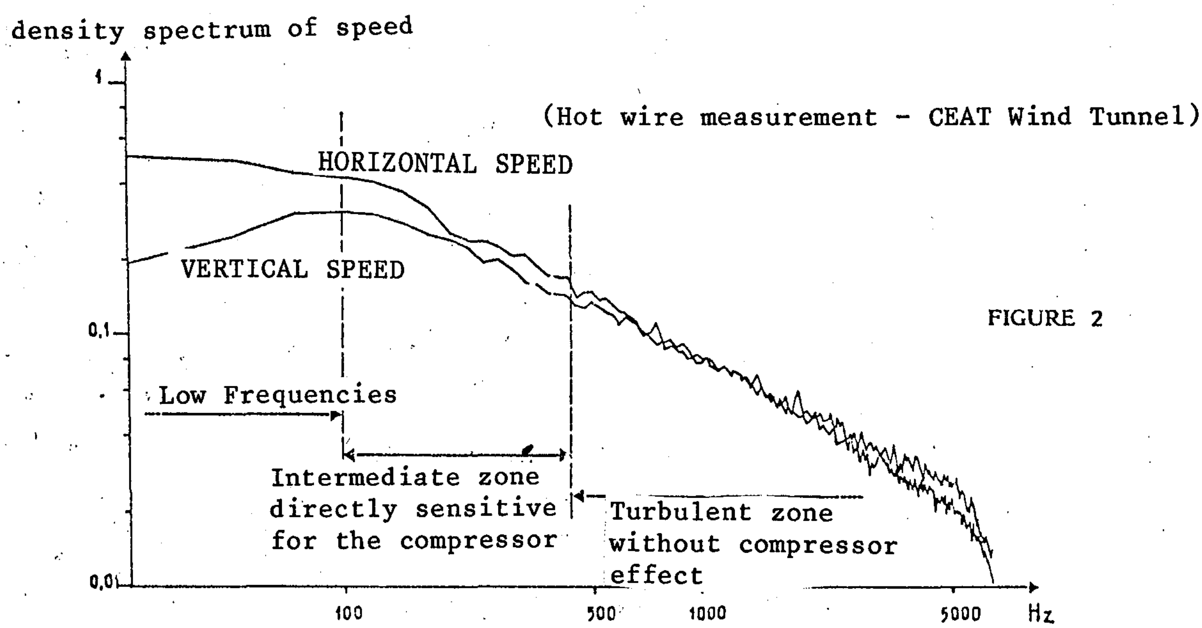
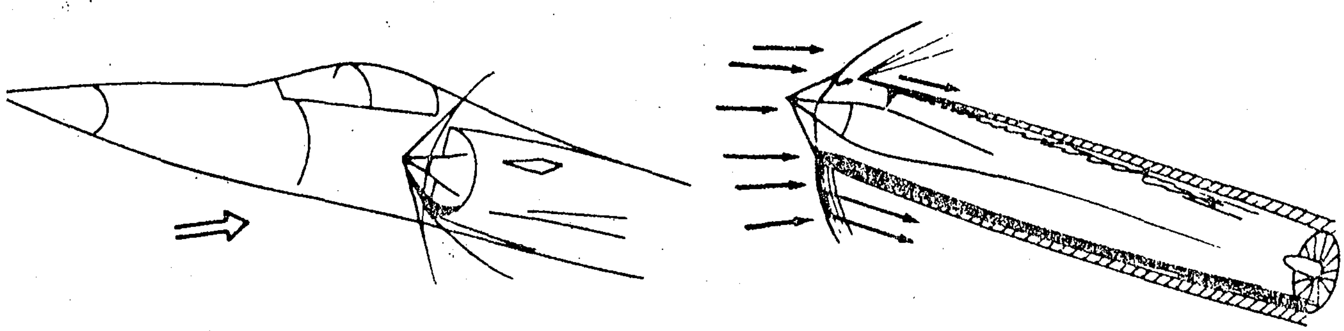


FIGURE 2

VARIOUS FUNCTIONS OF THE AIR INTAKE IN UNSTEADY MODE

a) Function at very low speed

b) Function at high Mach number



c) Function at high incidence in trans-sonic mode

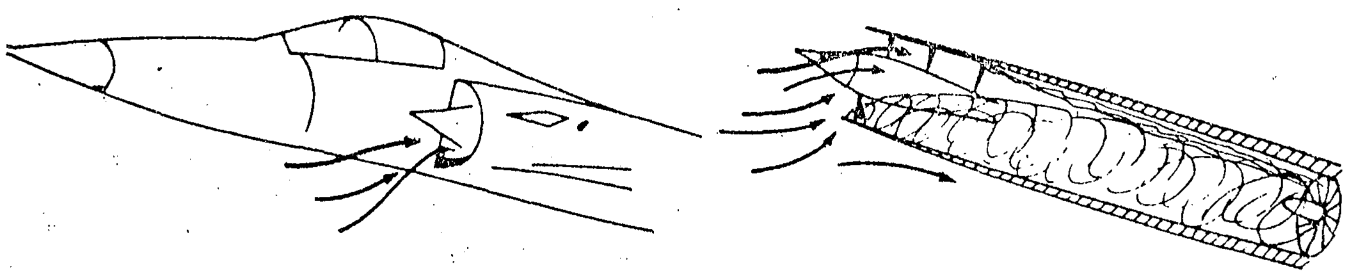
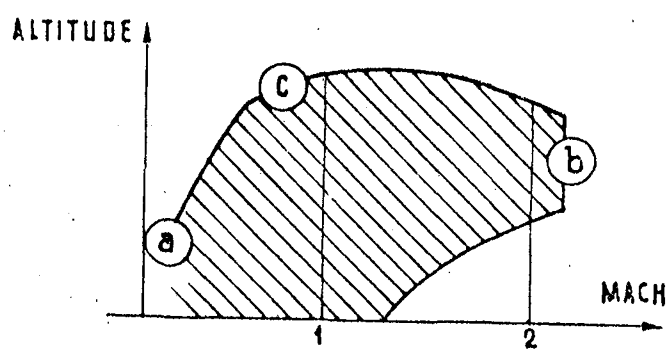


FIGURE 1



1.3. Historically, measurements of intake-duct/ jet-engine compatibility have led to a characterization of the steady stagnation pressure graphs in super-sonic mode and also to a notation of their maximal distortions, it being understood that the very unsteady abnormal functions of the duct (with buzz, pumping, etc...) must first be eliminated. Further, these graphs have been characterized over the entire flight domain of the aircraft and have been related to other problems encountered elsewhere, besides those of super-sonic flight. The very poor correlation obtained has led to the measurement of the graphs of unsteady stagnation pressure, and this has allowed a diminution of this general incoherence. However, the increased price of the test installation and cost of associated evaluations limits the generalization of this technique which is, in any case, quite incomplete. In consequence, we will present three paths leading to the economization of these elevated costs, by increasing their homogenity and efficacity, not only at the level of preliminary wind-tunnel tests, but also through bench- and in-flight testing. Without losing sight of economical research, means must be found for more accurate measurements of the unsteady turbulent airflows described in (1.2.2) above, with the help of measurements of local incidence and the coupled stagnation pressures.

In sum, it is necessary that we acquire more complete information on airflow more economically.

2. METHODS OF ACQUISITION AND ANALYSIS

2.1. Starting with a sufficiently rigorous definition of the unsteady graphs, an attempt can first be made to reduce the quantity of information to be processed by using statistical parameters of correlation in respect to the pre-processing of the data. Two economical courses are possible: either a general correlation of the spatial or temporal airflow at several points, deduced from a model, can be accepted a priori; or such a correlation can be accepted through deduction based on overall measurements in the airflow. The first course has been explored by Melick and produced interesting results through its economy of methods; this is described in detail in the references (Ref. 3 and 4). It presents the advantage of the possibility of a statistical control of its validity, hence an evaluation of its probable statistical error. But it led to masking of the instantaneous graphs beneath the selected probabilisitic model. It must be possible to systematically include an unsteady complement, starting with an evaluation at several points of the unsteady components, and a detailed overall steady graph. As the results do not depend excessively on the unknown law of probability for the fluctuations of airflow, and being limited to an average accuracy (20%) regarding the unsteady components, our experience has led us to recommend it in any case. To accept a correlation deduced from tests necessitates proceeding in two stages. Furthermore it is acceptable to adjust the coefficients of the Melick functions which have a certain theoretical value in proximate experimental measurements.

2.2. It is likewise possible to acknowlege that the measurements must allow a characterization of the critical points of operation of the compressor, but this necessitates data acquisition during a short interval of time of the entirety of the airflow. If it were possible to have an a priori understanding of the most realistic unsteady criteria for the jet engine, then the measurements of these would permit the retention, for detailed exploitation, of only the extremes of these criteria. An approximate evaluation of the extremes can be made starting with the detection, upstream, of the extreme coefficients of the map of the air intake, be they of the Melick type or be they more complete ones bearing on the local incidence and stagnation pressures. Thus this indication should permit the limited recording of the overall graph, with data bearing on the spatial and temporal correlations and on the average local turbulencies.

2.3. Below, in Part IV, is given the List of Specifications which was retained for the definition of the general system for acquisition and analysis, independently of all processes of minimizing the processing (standing rules of a priori statistical method) or the quantity of data stored (choice beginning with the upstream indicators of time zones where the experimental data gathered are stored and processed). Nevertheless, the quantity of data to be acquired and processed is very great.

/006/

Described in detail, below, is a process for the minimization of data storage and processing, the goal of which will be to permit, in the case of wind-tunnel tests where the constraints are the most difficult to satisfy (because of the proportionality of scale of the maximal frequencies to be considered), assurance of a continuity of direct tests and easier examination of the measurements. This has a double purpose:

- guiding the test engineer towards researching the most interesting configurations,

- pin-pointing the zones to study on digital or analogic magnetic tapes which record the totality of points measured.

3. MINIMIZED METHODS FOR DATA ACQUISITION AND PROCESSING IN WIND TUNNEL TESTS

3.1. If the maximum acceptable scale model size is maintained, in the large ONERA wind tunnels at Modane, this will be on a scale close to 1/5th, thus the maximal sampling frequencies are 5 times higher than in flight or on the test bench. As a large number of measurement points is required (Ref. 5) to characterize a duct as a function of the four parameters (upstream Mach number, Mach number at the compressor entry, incidence and yaw), and this for several configurations, it is very important to have available minimized methods of instantaneous evaluation of the quality of the airflow in order that the test engineer can better control the testing program. Such an installation for test observation in real time is habitually designated by the term "quick look".

3.2. The criteria for the definition of a good "quick look" are:

- maximum reduction of testing time (hence cost).

- maximum limitation of human intervention,
- possibility of utilizing the existing assist solution at the level of the Modane acquisition systems for local evaluation,
- possibility of simplification of the method, taking into account experience which will be progressively acquired.

Only the interesting zones where distortion is the greatest will be studied in real time (or quasi-real time). Therefore it is necessary to have a detector for these points in time. Knowing that the greatest distortions in the plane of the compressor are obtained when gross disturbances occur, a way must be found to detect this gross buffeting upstream of this plane. To this end some probes will be placed about a diameter upstream of the plane of the compressor. A simple criterion, based on the information furnished by these probes, will initiate acquisition, then processing, of the collective pressures of the RAKE ~~comb~~ during the passage of the disturbance at their level.

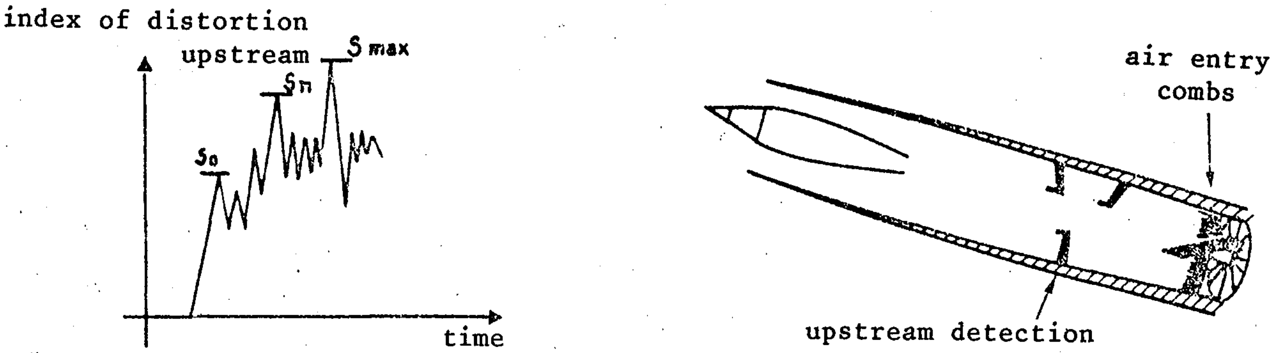


FIGURE 3

3.3. Index of detection:

It must be simple, because its calculation time must be clearly inferior to the propogation time of the airflow between the detectors and the plane of the compressor (~ 2 ms si X = 2D).

An experiment performed at ONERA showed that a stagnation pressure (with its maxima or its minima) is a bad index. On the other hand, the maximum difference between two stagnation pressures obtained at diametrically opposed points, in the plane of symmetry, predicted approximately 2/3rds of the peaks of the various coefficients of distortion. It must be noted, however, that all the coefficients of distortion envisaged (K, KD, IDC, IDR...) do not give the extremes at the same instant.

Thus, to detect the maximum of the distortion peaks, utilization of 4 to 6 detectors is envisioned; six being the maximum for two reasons:

- the quantity of data to be processed in real time,
- creation of wakes which disturb the airflow in the regions of measurement.

The index of detection now proposed is I_d = Pmax - Pmin for the "n" detectors installed.

3.4. Criterion of detection

The index of detection is calculated in real time, by an assembler program, with an acquisition frequency neighboring on 16KHz.

/007/

A decision was made for the interval of time "to", during which the maximum of the index of detection is sought, which will serve as the 1st threshold of detection.

$S_o = \mathrm{Max} \quad (I_d)$

$t = o$ at $t = t_o$

A delay interval for "to" of about 0.1 second is presently envisaged.

To take into consideration only those disturbances of a certain importance in consequence of their duration, an index was used averaging several acquisitions (three, for example).

It must be noted that this average is not equivalent to dividing the acquisition frequency of the detectors by three.

Such a calculation (6 detectors and n = 3) is presently best performed by an assembler programming for about 200 μs; a value compared to the 2 ms necessary for the airflow to cover the distance "detectors/measurement plane".

Thus, beginning at the instant $t = t_1$, where a first threshold S_o is defined, the acquisition will be initiated when:

I_d is greater than S_o

At this instant four actions occur:

a) timing impulse to the magnetic tape, for eventual retrieval of the zone for processing.

b) after an optional "delay time" t_r , designed to limit the quantity of data to be processed, the data gathered by the ~~comb~~ RAKE is slaved to the memory unit:

- 55 channels (possible extension to 64)
- acquisition: 16 KHz
- duration of acquisition, being about 3 ms: 50 readings per channel, corresponding to data of 50 values on 55 channels (maximum possible duration 16 ms).

c) calculation of a new detection threshold S1: this will be obtained by finding the maximum I_d which follows the triggering of the processing point.

d) inhibition of a new detection threshold before a "green light" which will be given eventually, in function of real time data processing.

3.5. Tests for choice of measurement points

When the "green light" is given to the detection system, the following triggering action will be effected when

I_d becomes greater or equal to S1, recycle.

The test will be considered as terminated when there has not been a detection during a predefined time (tm about 10 s). This will signify that during the time tm no disturbance greater than the last detected has occurred (problem posed in Para. 1).

It must be noted that if no disturbance greater than the threshold has occurred during the time to, there is no triggering. However, the value must be recorded, for example, at t = 0, to verify that there has not been an error (in defining the configuration being studied - point nr.) at the level of the threshold.

If this occurs regularly it signifies that the to is too large.

On the other hand, to obtain the processing of several points (and at least one, in the preceeding case), a new cycle is commanded with reset to t = 0 (S = 0).

3.6. Processing of the measurement point

The data acquired in the memory unit are transferred to the disk of the acquisition system's HP 2100. The processing required consists in calculating, for the 50 recorded points, the principal coefficients of distortion (K_o , KD, IDC, IRD) and in providing a print-out of the maximal values of these indices for the data acquired.

Such a calculation was performed by ONERA on an HP 21 MXF, with 36 pressures for the 4 indices defined above, in 220 ms.

/008/

4. GENERAL SPECIFICATIONS LIST FOR DATA PROCESSING

4.1. Compatability

For research organizations, aeroplane and jet engine manufacturers utilizing similar methods of airflow analysis, the exchange of data between the several partners should be organized in such a manner that each of them can obtain directly the information indispensable for the accomplishment of his individual objectives.

This requirement implies that a compatibility be developed as highly as possible between hardware and software, in such a fashion that it will guarantee that the exploitation of a measure of general interest will be immediate and identical to all of the participants.

Clearly, this compatibility must not retard individual research programs of those concerned.

4.2. Data acquisition

Data acquisition in the framework of research in the heterogenity of airflow must respect the various recommendations contained in the numerous existing documents which cover previously developed acquisition methods (Ref. 6 and 7).

The plane of measurements of stagnation pressures results from a unique communal definition; it will be situated as close as possible to the compressor entry without, however, significantly affecting the performance and stability of the turbo-engine, the effect of which would be to falsify conclusions drawn from evaluation of the compatibility between air intake and jet engine.

It will be recalled that research already undertaken has shown that it was important, in order to define with sufficient precision the circumferential homogenities, to utilize a minimum of at least eight equi-distant circumferential RAKES ~~combs~~. Thus, the comparison between scale-model and test-bench results will be made with an identical RAKE ~~comb~~ position in respect to the air duct.

Radial distortions will be recorded at five stagnation pressure points, by Rakes ~~combs~~ disposed over equi-surfaces. Complementary measurements of angle of incidence will be distributed over each of the rakes ~~combs,~~ as well as the measurement of total temperature.

Increased speed of data processing times are possible by means of a partial evaluation by a local computer, as one of the following reductions can be accepted:

- limitation of the number of measurement points (about 50),
- reduction of the number of coefficients of distortion calculated in the plane of measurements, for 2 ms,
- integration of the evolution of internal airflow at less than 3 diameters from the air intake.

4.3. Complementary measurements

Outside of the unsteady channels devoted to measurements in the upstream plane of the compressor, several steady or unsteady channels are necessary in order to record the supplementary parameters which are specific to each type of test (bench, flight, wind tunnel).

- the level of turbulence of the various static pressures, incidences..., wind tunnel references, flight.

- static pressure between stages, the total temperature at the jet engine air entry, certain characteristic parameters, residual unsteadiness at the compressor outlet,...., in the case of partial test bench, or bench test with engine.

- several engine parameters cited above, as well as information on the aerodyamics of the aircraft (incidence, yaw, Mach number) and on the ducting, in the case of measurements on the aircraft.

In contrast to the channels for measurement of stagnation pressures only, in each case about 20 channels can be assigned to diverse applications and evaluated; the specification calls for a total of 64 unsteady channels capable of being recorded without unacceptable inter-channel reactions.

4.4. Band Pass

The useful band pass for dynamic phenomena is determined by the relative influence that it has on the functioning of the jet engine. Thus the distortions of upstream airflow at very high frequency (above 4 times the rotational speed of the engine) have little effect upon the stability of the compressor.

The best correlation coefficient, distortion vs. pumping margin, is obtained with a pass band which can be varied according to the compressor used (number of rotors, chord of the mobile wheel,...), but which remains, however, close to the rotational speed of the engine. Figure 4 demonstrates the variation of the maximum IDC coefficient with the pass band. It is observed that its evolution about the frequency corresponding to the rotational speed of the engine is significant; the results will depend upon a choice of useful band pass.

/009/

It must also be recalled that it is necessary to take into account the scale factor in order to correct the pass bands between tests on scale models and tests at scale 1.

Therefore, if it is considered that the maximal rotational speed of a fan is about 250 Hz (being some 15,000 RPM), the useful pass band will not exceed 1,000 Hz at the scale of the engine. In the case of a model at 1/4 scale, the useful pass band will then be some 4,000 Hz. If the data acquisition is numeric, a sampling ratio equal to four times the pass band is sufficient to avoid spectral saturation and other errors due to storage in memory.

Clearly, this pass band must be variable, according to the type of measurement effected, notably during studies of transitory or unstable modes.

4.5. Data acquisition time and total volume

The acquisition time must be sufficiently long so that calculation of the instantaneous coefficients of distortion gives a representative maximum, and short enough to avoid an accumulation of superfluous data. As an indication, Fig. 5 gives a characteristic example of the coefficients of distortion calculated for an air duct. It can be seen that times of the maxima are extremely variable, according to the coefficient of distortion as well as the band pass being considered. It is accepted, with most researchers that in most cases, at the scale of the engine, 30 secs. are sufficient for the characterization of point of operation. Such duration of acquisition could be obtained, in stabilized flight configuration, for only a limited number of points in the flight domain. For the others, they will be obtained by repetition of the tests (Fig. 5).

Finally, the number of tests can be extremely variable according to the difficulties encountered during the course of development of the machine, and require a continuation in minimum real time in order to orient the measurements in the important zones to be studied.

Figure 5 gives an example of the sensitivity to these parameters, of the result of calculating the DC60 coefficient, which shows that the result is a direct function of the pass band and the calculation time. Figure 6 gives an example of the evaluation of the continuous calculation of instantaneous parameters.

The preceeding considerations necessitate that the system be capable of acquiring, as a minimum, 64 x 1,000 x 4 = 256,000 numeric timed data per the second, at the scale of the engine. In the wind tunnel, the number of data per second is multiplied by the scale factor of the model. In aggregate, the number of data remains identical and approaches 7-million (in 30 seconds) for a scaled configuration.

In conclusion, it is desirable that several tens of cases should be recorded before a modification of the support equipment.

These data should permit a reconstruction of the complete experimental field of extreme speeds, analogous to the theoretical field drawn in Figure 7, and which is the result of the unsteady calculation, at a given instant, of the Navier Stokes equations.

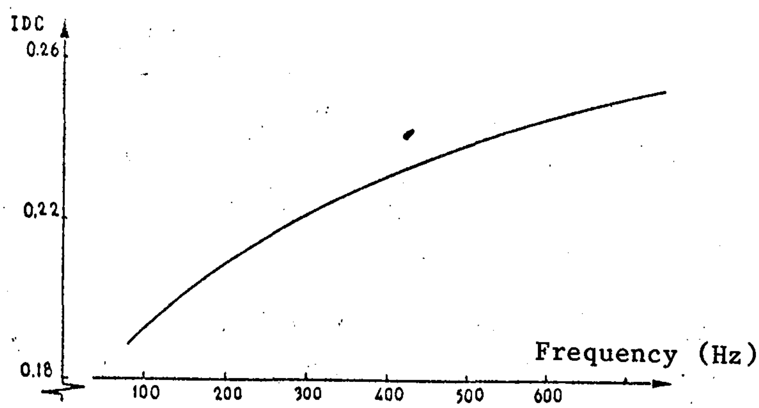


FIGURE 4

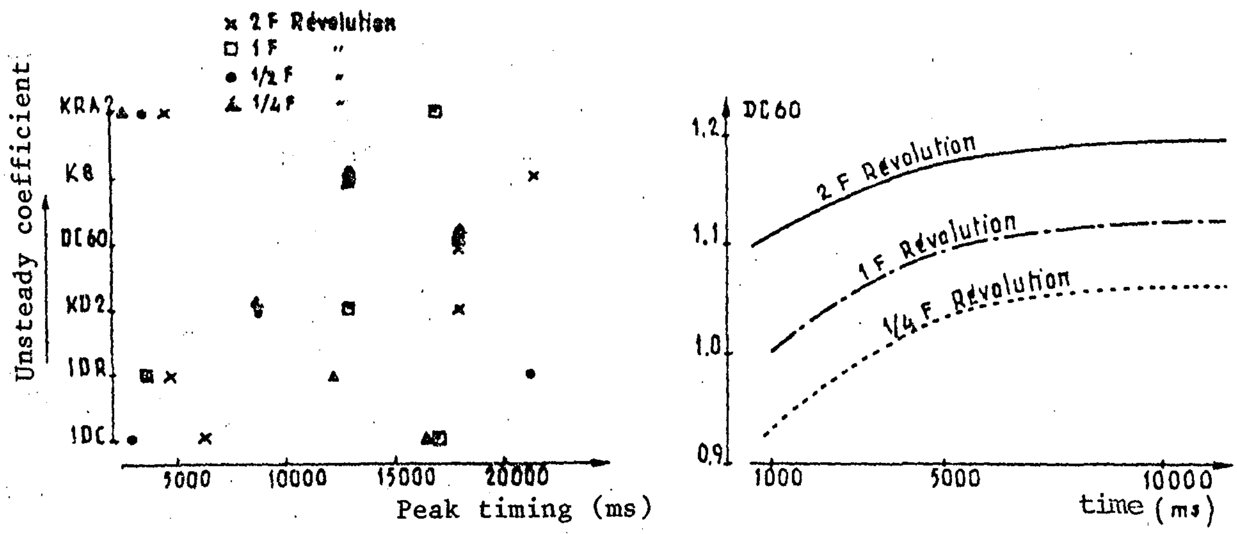

× 2 F Révolution
□ 1 F "
● 1/2 F "
▲ 1/4 F "
Unsteady coefficient
KRA2
K8
DC60
KD2
IDR
IDC
5000
10000
15000
20000
Peak timing (ms)
DC60
1.2
1.1
1.0
0.9
2 F Révolution
1 F Révolution
1/4 F Révolution
1000
5000
10000
time (ms)

FIGURE 5

COEFFICIENTS OF DISTORTION

AND UNSTEADY STAGNATION PRESSURES

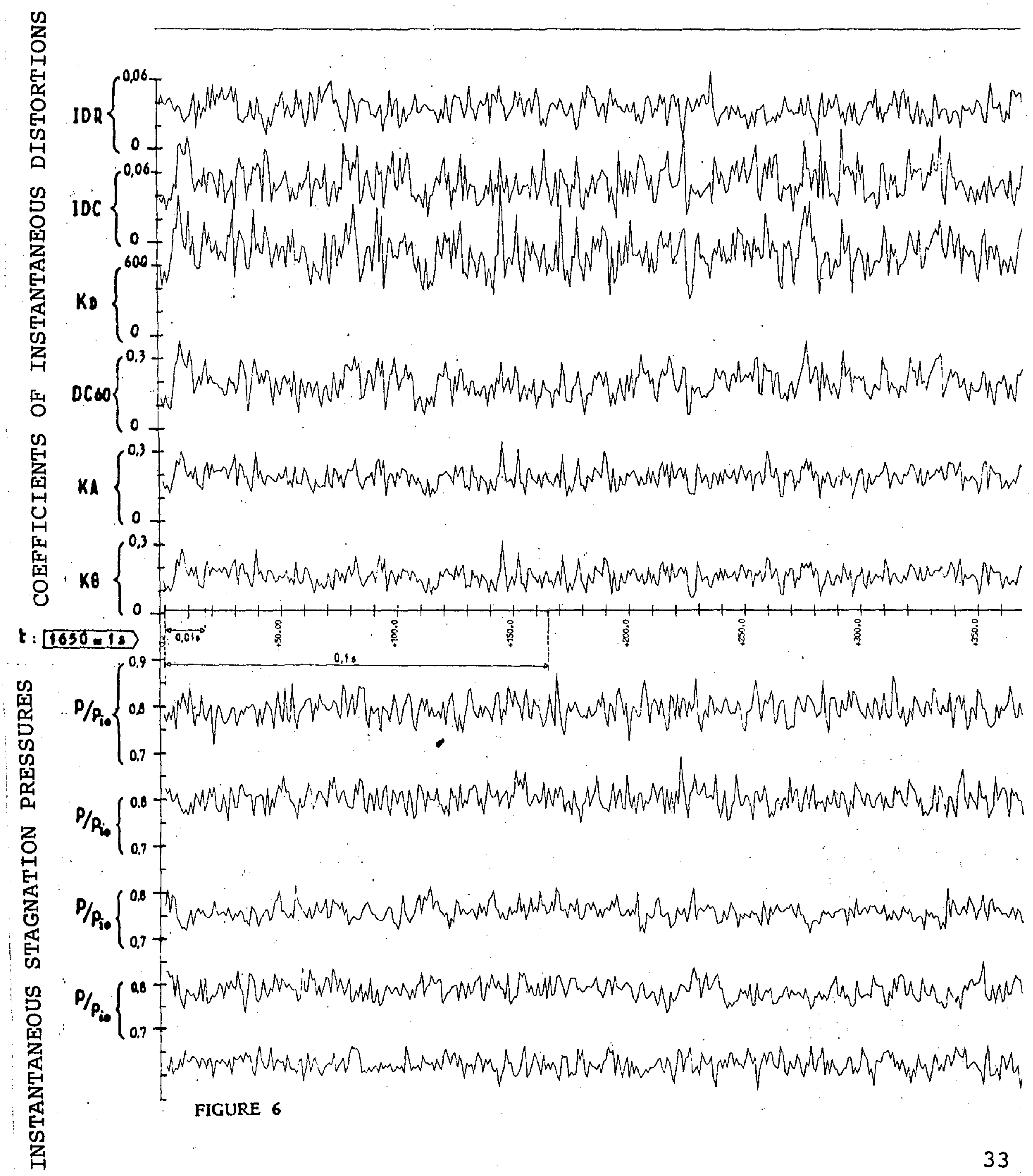


FIGURE 6

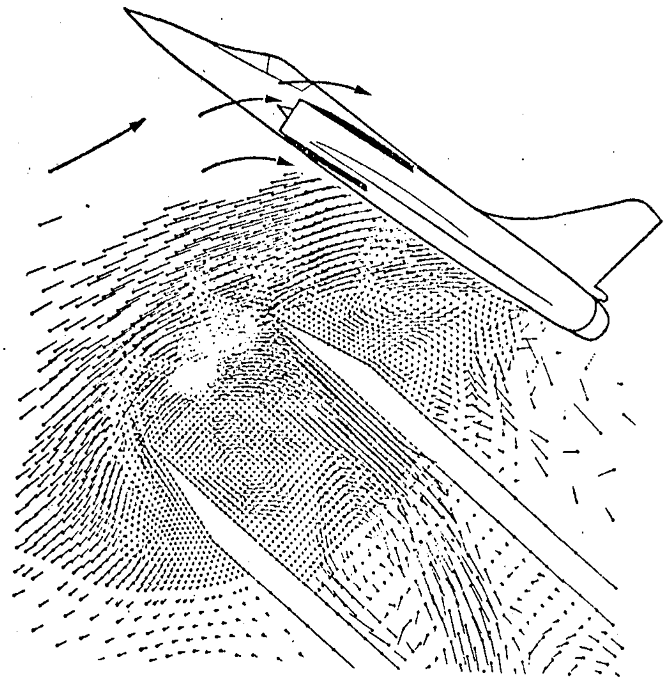


FIGURE 7

4.6. Precision of measurements

4.6.1. Determination of the loss of margin induced by upstream heterogenity, if it depends on the methodology (coefficient utilized, band pass, etc...), requires a good precision on the measurement of the physical size.

The fixed objective is to effectuate measurement with a theoretical precision neighboring on 5% in regard to the unsteady part, the resulting overall precision being admittedly less good. The precision characterizes the fidelity of the tests.

Two major sources of imprecision will be distiguished:

1) the precision of the transducers, the sensitivity drift of the transducers and the gain of the amplifiers,

2) non-synchronization between channels, amplitude distortion and the filter system.

4.6.2. Unsteady transducers having the required level of precision are available, but they must be assured of an adequate environment. The transducers will be protected for the purpose of avoiding rapid deterioration in polluted atmosphere without, however, limiting the useful pass band. And special handling of thermal problems is necessary to avoid excessive thermal drift, especially in flight and in the wind tunnel (Ref. 8).

Because of the impossibility of guaranteeing faultless operation of the collectivity of transducers, the replacement of deficient transducers is ensured by an average evaluated on neighboring transducers:

- the steady part, if necessary, will be calculated on the basis of n (n = 3 or 4) adjacent steady probes p_{TSS} :

$$p_{T_{SS}} = \frac{\sum_{i=1}^{n} \frac{1}{R_i} \, p_{T_{SS}}}{\sum_{i=1}^{n} \frac{1}{R_i}}$$

R_i : distance between the probe being considered and the deteriorated probe

- the unsteady part will be calculated similarly, based on n adjacent unsteady probes:

$$p_{T_{INS}} = \frac{\sum_{i=1}^{n} \frac{1}{R_i} \, p_{T_{INS}}}{\sum_{i=1}^{n} \frac{1}{R_i}}$$

R_i : distance between the probe being considered and the deteriorated probe

Furthermore, an inspection by value check must be effectuated systematically before and after tests.

4.6.3. Non-synchronization between channels is a source of error which arises either from a static or dynamic discrepancy between channels in the case of a analogic recording system, or from the non-synchronization of samplings in the case of digitization. A sampler-blocker per channel can be indispensable in assuring

TABLE 1

TYPE OF FILTER
ANALOG FILTER F=630 Hz 48 dB/oct.
HANN TUKEY SPECTRAL MULTIPLICATION Spectral definition ($A(f)=1$ $(f)<f$ ($A(f)=1/2\ (1+\cos\pi \frac{(f-f1)}{(f2-f1)}$ $f\leqslant f\leqslant f2$ ($A(f)=0$ (f) f1=156 Hz 48 dB/oct. Half-length = 30 samples f1=156 Hz 60 dB/oct. Half-length = 30 samples f1=156 Hz 60 dB/oct. Half-length = 60 samples f1=156 Hz 60 dB/oct. Half-length = 20 samples
BARTLETT SPECTRAL MULTIPLICATION Spectral definition $A(f)=1$ f f1 $A(f)=\frac{1}{9}\ (3+4\cos\pi \frac{(f-f1)}{(f2-f1)} + \cos 2\pi \frac{(f-f1)}{(f2-f1)})$ $A(f)=0$ $(f) \geqslant f2$ f1=156 Hz 48 db/oct. Half-length = 30 samples
CONVENTIONAL SPECTRAL SMOOTHING Over five weighting points (1/5, 1/5, 1/5, 1/5, 1/5). f1=156 Hz 48 db/oct. Half-length = 30 samples
HANN TUKEY SPECTRAL SMOOTHING Weights (1/4, 1/2, 1/4). f1=156Hz 48 dB/oct. Half-length = 30 samples
BUTTERWORTH RECURSIVE FILTER f=156 Hz 9 poles

TIME AT MAXIMUM	RELTIVE TIME FOR CALCULATION	RELATIVE VAL. OF K INST.
T		100
T	162	89.9
T	162	89.7
T	278	89.8
T	123	89.8
T	161	87.1
T	158	85.1
T	158	85.8
T	100	86.0

synchronization of sampling, taking into consideration the wide pass band required.

Amplitude distortion is set by IRIG recording standards and is increased as the linear level of operation is raised. The error due to background noise results from a compromise with the amplitude distortion error. In effect, to avoid clipping the signal peaks, it is desirable to record at several decibels below full scale. The consequence of this is to diminish the useful dynamic range. This error can reach several percent. The dynamic range of a PCM type system is defined by the number of bits in the analog-digital conversion (being 60 dB for 10 bits) which, with a margin of 6 dB, produces and error of 0.2% for this type of recording.

/012/

The type of filtering, be it anlogic or digital, is also a source of imprecision.

It must be remembered that the error attributable to phase distortion is due to the fact that the quadripolar transfer function is complex and modifies, at the same time, both the amplitude and the phase of the signal traversing it; this occurs at three points in the system:

- the analog recorder, if this type of recorder is used,

- the isolation filter, before analog-digital conversion, if a conventional filter is used,
- digital filtering during processing, if a recursive filter is used.

The simulated low-pass filters can also be, during digital processing, a source of imprecision arising from the type of filter used or from the desired precision, operating to the detriment of the time of calculation. Table 1 presents an example of the response of various types of filters from the point of view of time of calculation, phase distortion and the maximum value of the coefficient of distortion K inst..

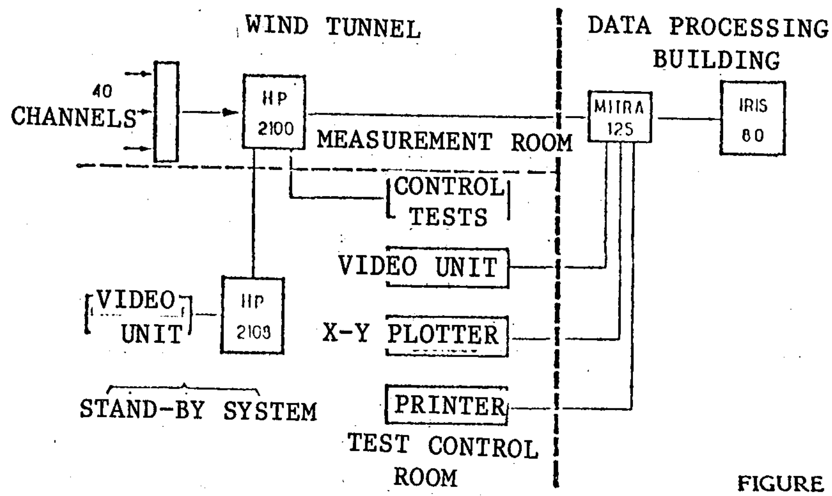
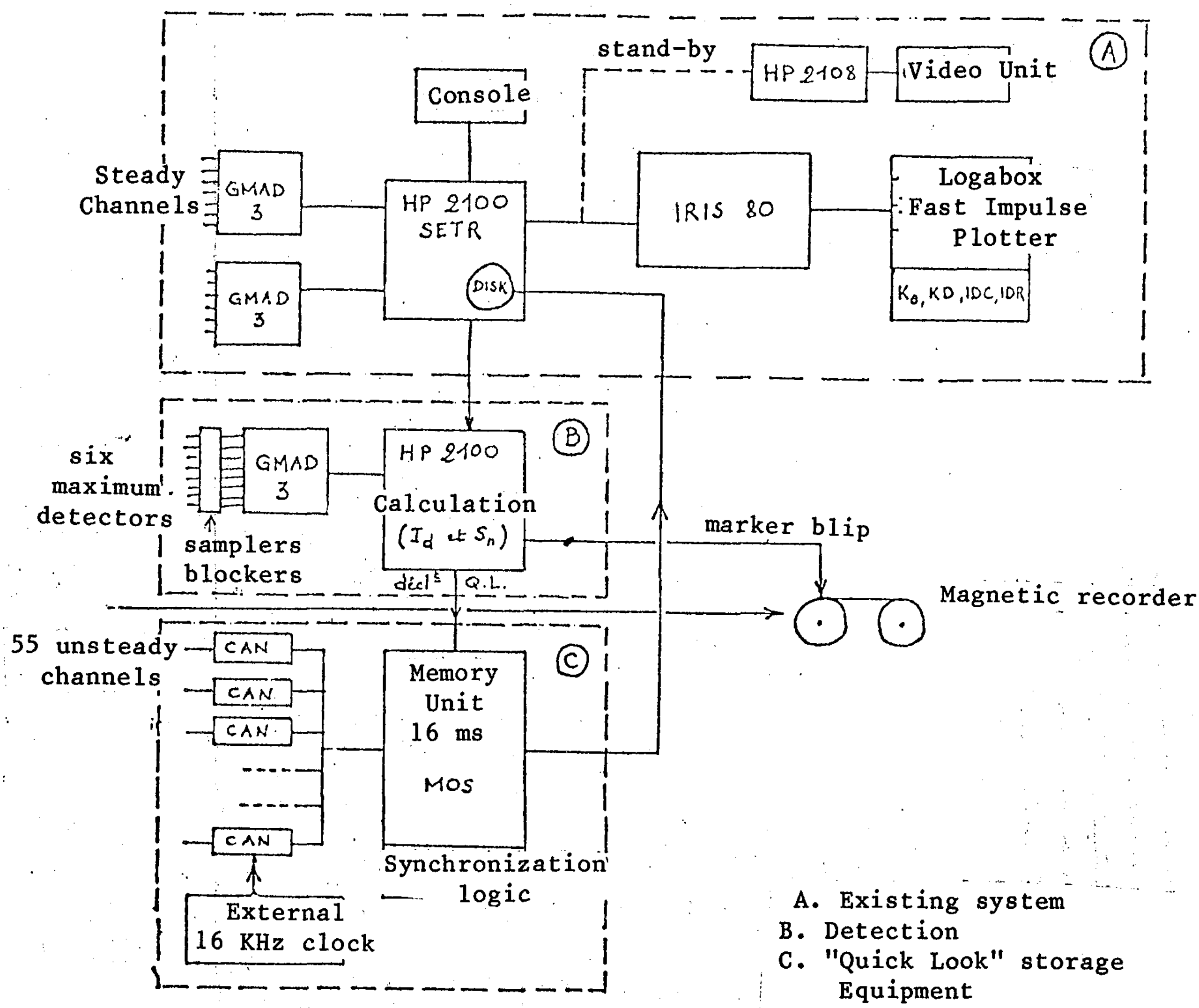


FIGURE 8

SYSTEM FLOW-CHART



The type of filter selected - spectral multiplication or spectral smoothing - can exercise a large effect on the results, while the length of the filter, or even its slope, have less effect on the results. The Butterworth 8-pole recursive filter is particularly effective with regard to time of calculation; however, it necessitates quadruple precision programming to assure digital stability and introduces a considerable phase displacement. It is, however, impossible to set standards when considering existing wind tunnel or flight systems.

5. PROPOSED SOLUTIONS

5.1. As to the general implementation of the measurements system, the attached drawings describe the installed equipment for data acquisition and analysis. It consists of:

- mechanism for rapid detection,
- mechanism for test bench or wind tunnel acquisition,
- mechanism for in-flight acquisition.

5.2. Wind tunnel tests

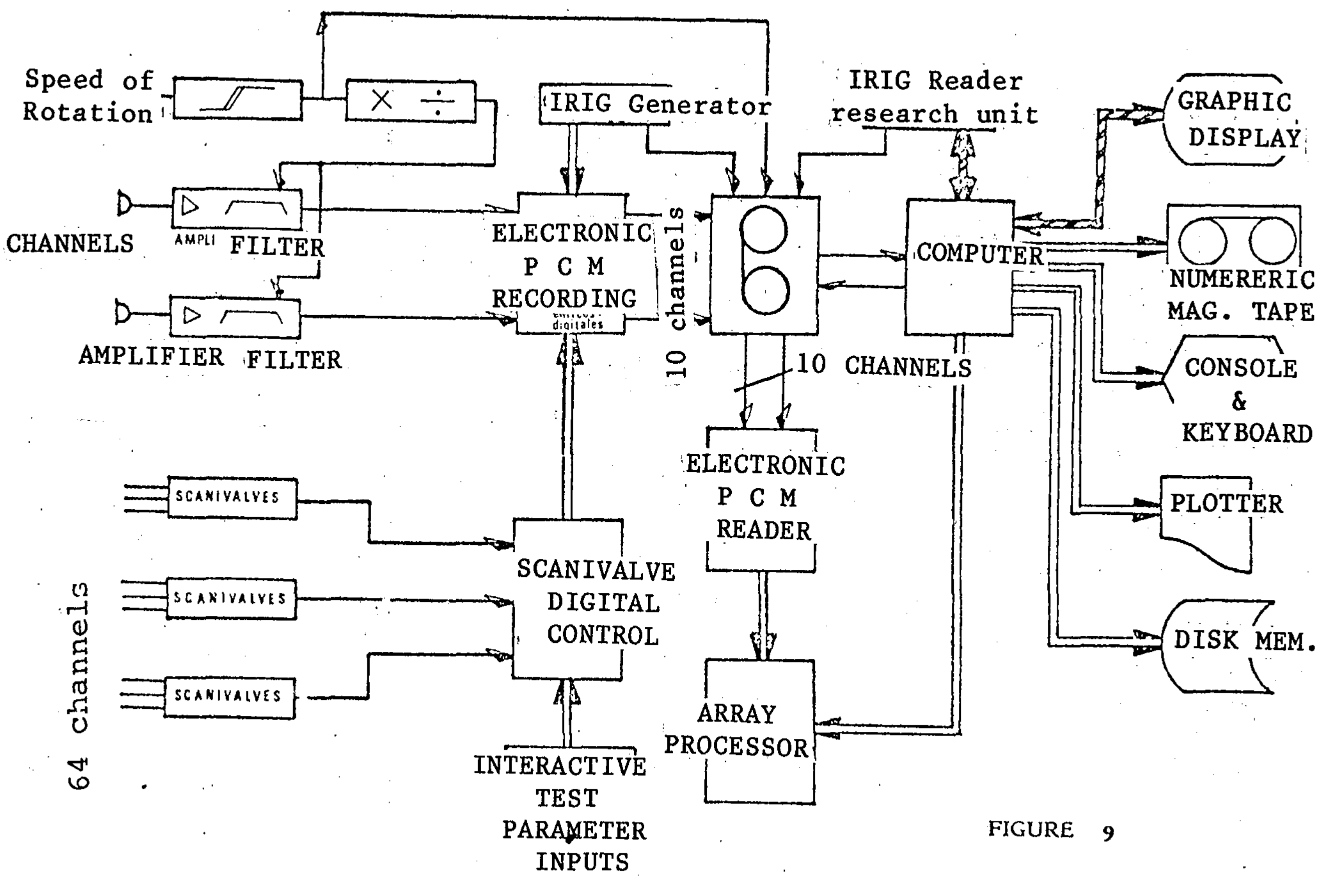
The mechanism used for rapid detection operates in conjunction with the CII IRIS 80 computer at the Modane Center.

/013/

The list of sequences and tests is as follows:

- a disturbance is detected;
- after an optional delay time the digital values characterizing 50 instantaneous maps are stored in the memory unit;
- this body of data is transmitted to the wind tunnel 2100 disk;
- this disk is immediately dumped to the IRIS 80 which can begin procesing;
- the disk now being empty, the "green light" can be given for the following detection.

Thus the entire acquisition, through the completion of system operation, can be made very rapidly; there is no waiting period for data processing between two acquisitions from the same configuration.



Speed of Rotation
IRIG Generator
IRIG Reader research unit
GRAPHIC DISPLAY
CHANNELS
AMPLI FILTER
ELECTRONIC P C M RECORDING
10 channels
COMPUTER
NUMERERIC MAG. TAPE
AMPLIFIER FILTER
10 CHANNELS
CONSOLE & KEYBOARD
ELECTRONIC P C M READER
SCANIVALVES
PLOTTER
SCANIVALVE DIGITAL CONTROL
SCANIVALVES
DISK MEM.
64 channels
SCANIVALVES
ARRAY PROCESSOR
INTERACTIVE TEST PARAMETER INPUTS

FIGURE 9

In parallel, the IRIS 80 is working and outputting to a Logabox plotter the coefficients of maximum distortion calculated for each detection.

This method permits a reduction of testing time, but is admittedly working in quasi-real time.

Joining the central computer to the test surveillance system presents the problem of its availability. Alternatively, the test can be performed by the stand-by system normally in place at Modane, and this consists in a reduction of processing (10 data sets instead of 50, for example, to be processed immediately) performed by the HP 2108 (the other data sets are, however, on the 2100 disk and thus tranferrable to the IRIS 80 at a later time).

All acquisitions of a series of measurement data sets will be followed by an output detailing the maximum coefficients of distortion, without being limited to the single output of the last acquisition, which corresponds to the maximum index of detection encountered during the test. In effect, the various coefficients of distortion, not being maximal at the same instant, they will thus not necessarily all be maximal at the time of the last acqusition.

5.3. Test bench

Based on the general specifications set forth above, a complete system of data acqusition and processing has been defined. This system is capable of measurements at the wind tunnel, on the test bench and in flight.

The option chosen for recording and data processing is entirely digital, thanks to the high-performance equipment presently available on the market.

The major operational principals of the system as applied on the engine bench are shown in Figure 9.

/014/

- Input conditioning

The 64 unsteady signals are amplified by variable gain amplifiers in such a way that drift in the sensitivity of the transducers can be compensated, then they are filtered by a high pass filter at 0.5 Hz and a transverse low pass filter controlled by the rotational frequency of the machine.

The steady measurements are acquired by a unique transducer switched by a scanivalve.

- Recording

The PCM recording system assures digitization without phase distortion, at a variable rate, and recording the unsteady signals acquired separately by scanivalve. An IRIG time base is also on the same tape with the unsteady signals, and the steady channels acquired can be mixed.

/015/

In the case of recording with calculations in real time, the computer can write marker signals onto the tracks to allow selection of incidents of interest with a view to evaluation at a later time.

- System for real time calculation and evaluation

This is the same system which is used for real time calculations and evaluation.

It includes an array processor which assures the re-evaluation of defective transducers, filtering of digital signals (if necessary) and the calculation of simple coefficients in real time. Search and flagging of incidents where the coefficients exceed a specified threshold is performed by the computer.

At a deferred time, the system is capable of performing all the numeric calculations of the complete recording.

A certain number of peripherals (high-speed plotters, console and keyboard, disks, etc...) are interfaced to the computer. Also planned are data links with the test bench and a central data base.

5.4. Flight testing

The system employed, utilizing the same type of data acquisition as on the test bench, is too heavy and too voluminous to be installed in a combat aircraft such as the

MIRAGE 2000. Also, for the measurements of distortion on this aircraft, to be requested at an early date is a multiplexed analog FM recorder, where the perfect synchronization required between the different tracks is obtained by use of an IRIG time base on each head. This method has been successfully tested in the past and raises no fundamental difficulty at the technological level.

CONCLUSION

Starting with the needs for evaluation of the aerodynamic field at the air compressor entry of jet engines, and what can be accomplished with the means of acquisition and processing presently available, the specifications and details of the implementation of a collectivity of measurements has been presented. The unsteady aerodynamic characteristics at the entry of the air compressor can, in this way, be measured with a satisfactory reliability on the test bench, as well as in the wind tunnel or in flight. The interpretation of the results should permit progress to be made in the evaluation of the compatibility between air intake and jet engine, by means of the choice of criteria of unsteady sensitivity and, in consequence, permit a better adaptation of the engine and enclosures under the most severe operational conditions to which the new military aircraft are subjected.

ACKNOWLEDGEMENTS

The authors wish to thank various personnel at ONERA and M. CZINCZENHEIM (AMD-AB) for their recommendations and assistance in pefecting the analog acquisition system presently employed for all industrial air intake tests in ONERA at Modane, and their advice and recommendations for the new system in course of construction and which is described in this paper.

- For the definition of the AMD-BA in-flight tests system: MM. COSTARD and PATUREAU
- For the evaluation of tests: The Department of Experimental Aerodynamics of AMD-BA and the specialized personnel of the Large Test Facilities at ONERA.
- For the definition of technical specifications: M. EYRAUD and AUZOLE of the SNECMA.

REFERENCES

1. P. BOHN: Aerodynamics of the New Generation of Delta Wing Combat Aircraft - Fighter Aircraft Design - AGARD CP241.

2. G. KARADIMAS, M. GOUTINES, B. DELAHAYE: Measurements of Unsteady Flow in Air Intakes - Preliminary Studies - SNECMA internal report.

3. MELICK, YBARRA, BENCZE: Estimating maximum instantaneous distortion from inlet total pressure. RMS measurements AIAA 78 - 970.

4. STEVENS, SPONG, OLIPHANT: Evaluation of a Statistical Method for Determining Peak Flow Distortion Using F.15 and F.18 Data AIAA 80 - 1109.

5. G. LARUELLE: Study of Unsteady Distortions in Air Intakes at High Incidence - L'Aeronautique et l'Astronautique 1981 (to appear).

6. SCHWEIKHARD: Test Technics, instrumentation and data processing, AGARD LS-72.

7. ARP 1420 - March 1980 - Gas Turbine Engine Inlet Flow

Distortion Guidelines.

8. M. GRANDJACQUES: Measurements of Unsteady Flow in Air Intakes - L'Aeronautique et l'Astronautique Nr. 74-1979.

* * *

* *

*